HURRICANE HILDA, 1964

III. DEGRADATION OF THE HURRICANE

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ABSTRACT

As hurricane Hilda approached the Louisiana coast it began to entrain more and more of the cool dry air situated over the continent. This resulted in a diminution of the storm to a lesser level of intensity while the center was still well offshore. A much more rapid increase in central pressure occurred after the eye passed inland and the supply of oceanic moisture and heat became inadequate to support a hurricane. Finally, the storm rapidly acquired extratropical characteristics and moved eastward off the southeastern coast.

1. INTRODUCTION

Hurricane Hilda reached its most intense stage (941 mb.) shortly after the extensive research flights of October 1, 1964 [2, 3]. Filling began a little after 18 GMT on the 1st at the rapid rate of about 1 mb./hr. There is no conclusive evidence as to the reason for this abrupt reversal in tendency (see fig. 1 of [2]); however, the Gulf States had recently been overrun by a relatively cool, dry polar High. As Hilda progressed northward across the Gulf increasing entrainment of this air is thought to have halted the intensification underway on October 1 and led to filling. After landfall on October 3, the filling became extremely rapid and by October 5 the storm had become extratropical. This final part of our study of hurricane Hilda describes the approach of the storm to the coast and its degradation into an extratropical wave during the period October 1–5, 1964.

2. APPROACH TO COAST

Figure 1 is the time-space cross section of temperature anomaly for Lake Charles, La., composited in relation to the distance from Lake Charles to the moving center of

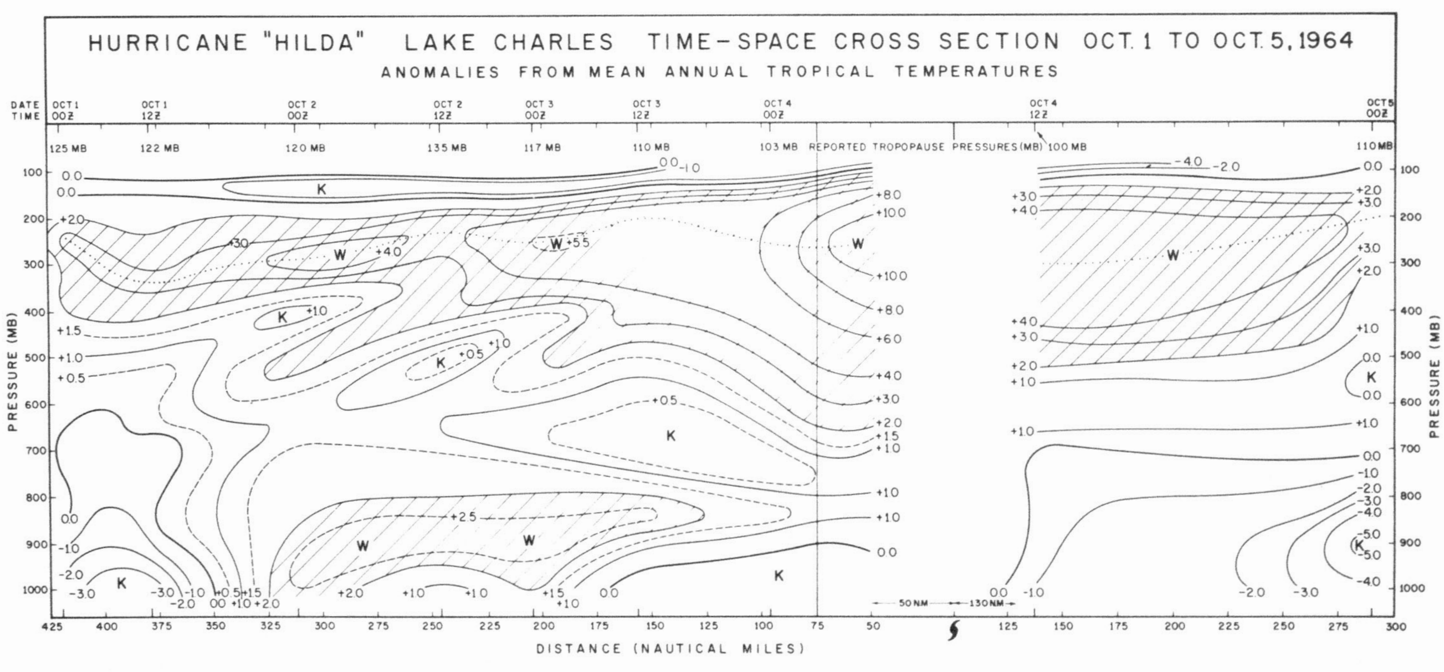

FIGURE 1.—Lake Charles, La., time section of raobs plotted on a space scale proportional to the radial distance to the center of hurricane Hilda. The values used at 50 and 75 n.mi. were composited from analysis of the aircraft data. The cool air that overlay the continent is partially reflected in the low level temperatures of October 1 and the deeper cold outbreak following Hilda is readily evident on October 5.

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the hurricane. Data gathered on October 1 in the interior of Hilda by research aircraft were added at the 50- and 75-n.mi. radial distances. The cross section suggests that on the 1st at low levels a cold wedge of air represented the remains of the recent polar intrusion at Lake Charles. As the hurricane approached the coast this air was entrained in its outermost circulation and was replaced by tropical maritime air of Gulf origin, i.e., temperatures increased 6.3°C. between 12 GMT of October 1 and 00 GMT of October 2. Perhaps a more valid comparison is that of the 24-hr. temperature change (between 12 GMT temperatures on October 1 and 2) in which the warming was 3.0°C. It is our contention that because of the entrainment of this cool air, the hurricane could be maintained, but only at a weaker stage of intensity, i.e., around 960 to 965 mb. Pressures of this order were noted throughout October 3 after the rapid filling of the previous day.

Although the central pressure rose rapidly during the 2d, the overall characteristics of the storm changed little. As we have seen in [2], most of the filling took place in the innermost core of the storm. Figure 2 shows the situation at sea level, 500, 300, and 150 mb. at 12 GMT on October 2. Warmer Gulf air was clearly present at Lake Charles as shown by the low level circulation. The 500-mb. map suggests little or no inflow, as was also true on October 1 at this level. Further, neither the 300- nor the 150-mb.

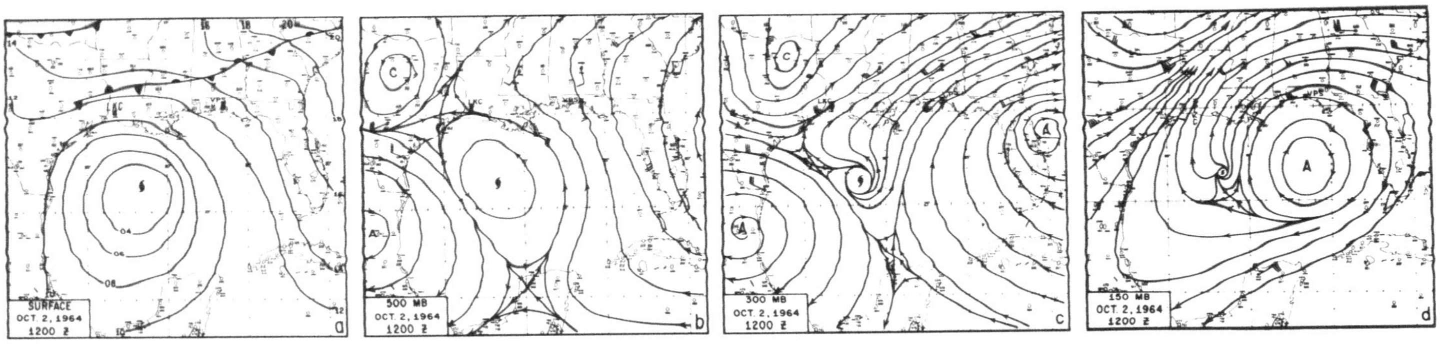

FIGURE 2.—Maps at 12 GMT, October 2: (a) surface isobars; (b) 500-mb. streamlines; (c) 300-mb. streamlines; and (d) 150-mb. streamlines. Lake Charles was on the western periphery of the outflow from hurricane Hilda at 150 mb. and appears to be within the cyclonic envelope at 500 mb.

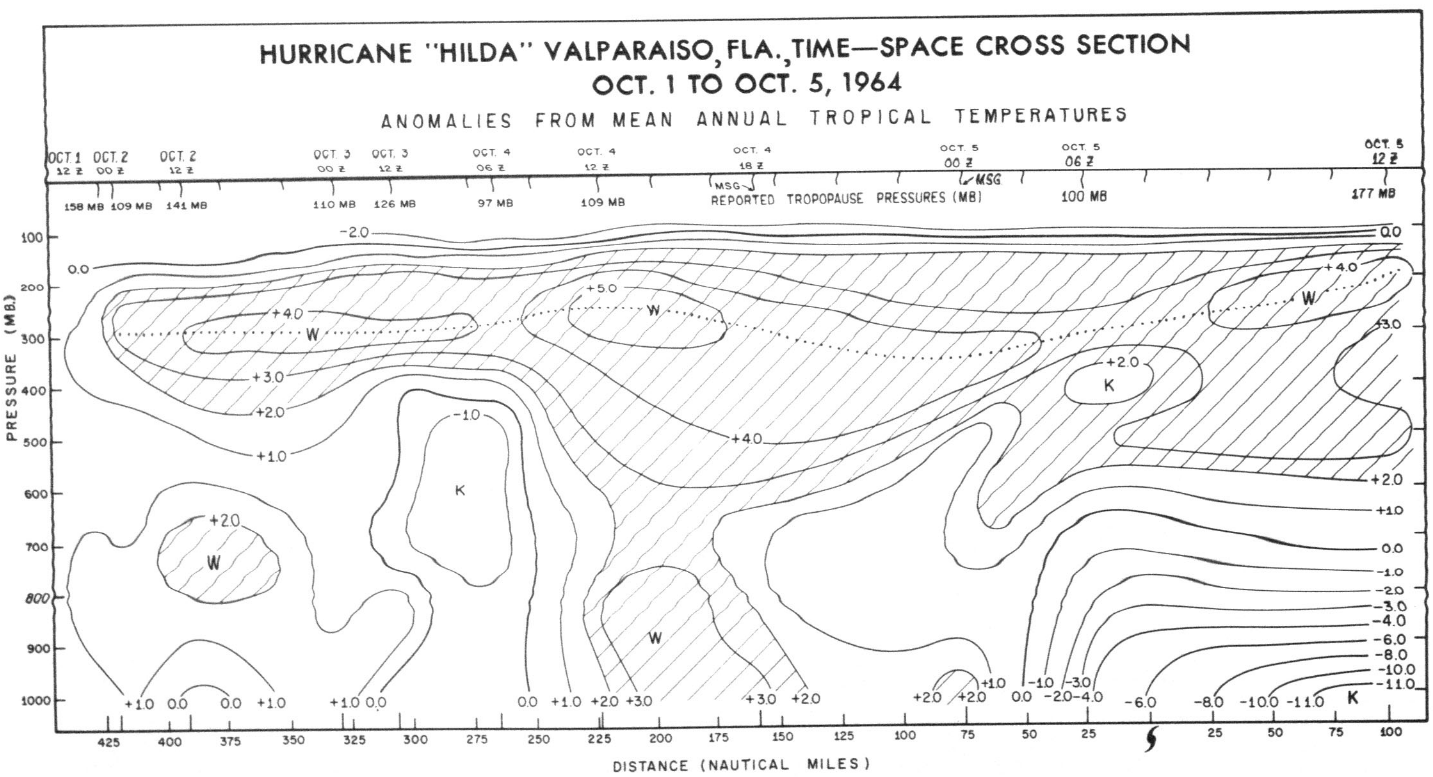

FIGURE 3.—Time-space section for Valparaiso, Fla., showing the warm outflow at elevation and reasonable lower troposphere temperatures as Hilda approached. When Hilda passed the station on October 5, however, it was already an extratropical wave with cold air at the lower levels.

map suggests marked advection of exceptionally warm air from the hurricane center. The outflow current was far from cold but it was not notable for its *exceptional* warmth. It appeared to be divergent and presumably air from below and perhaps some from above was entrained into this stream.

At the 300-mb. level, Lake Charles was on the outermost western edge of the envelope of stations receiving air exported from the central storm area. The major contribution to the flow over Lake Charles appeared to come from upstream in the westerlies. Despite this fact, temperatures were more than 4°C. above the tropical normal. At both the 200-mb. level (not shown) and the 150-mb. level the air appeared to be wholly a part of the diverging stream from the hurricane. Temperatures were 3.3°C. above normal at 200 mb. and −0.9°C. below normal at 150 mb., despite the proximity of the warm source. Although these temperatures did not seem to delineate a unique well-marked warm outflow, we found that neither Lake Charles, La., nor Valparaiso, Fla., showed any warmer outflows (around the 200-mb. level) even as the hurricane approached closer to these stations.

The time-space cross section for Valparaiso (fig. 3) suggests that by 12 GMT of October 2 the outflow from the storm was already reaching that location at the 300- to 150-mb. levels. Temperatures were some 4.0°C. above normal at 300 mb. and 0.4°C. above at 150 mb. More to the point, possibly, are figure 4 which shows the satellite photograph for Hilda at 1926 GMT on October 2, some 7 hr. later, and figure 5 which shows the nephanalysis, 200-mb. streamlines, and surface observations and fronts. Lake Charles appeared to be on the northwestern edge of the dense cirrus outflow and Valparaiso was close to the eastern edge of the same cloud sheet. Interpretation of cloud brightness where the photographs have been composited presents some difficulties but other frames show that the outflow cirrus did extend into southern Mississippi and Alabama. The dense clouds over eastern Alabama, Georgia, South Carolina, etc. appeared to be associated with the frontal activity along the southeast Atlantic coast (fig. 2a).

By 12 GMT of the morning of October 3 the hurricane center was about 75 n.mi. off the Louisiana coast and some 155 n.mi. from Lake Charles. Figure 6 from the TIROS VII satellite presents an oblique view of Hilda and some of the frontal cloudiness farther east and northeast. The maps for this synoptic time (fig. 7) show that a new burst of cool air had arrived on the scene at sea level, with the cold front trailing from northern Louisiana to western North Carolina. The old cold front was dissipating and being replaced by the new surge. At 500 mb. the area covered by cyclonic circulation appeared to have increased and temperatures had increased more than 1°C. at Lake Charles but may have decreased half a degree at Valparaiso. The cyclonic turning of the winds over Mississippi and Alabama gave way to marked anticyclonic circulation over Georgia. In association with these features showers and rain on the Gulf Coast extended east to Tallahassee and up into central Mississippi and Alabama. Georgia reported fog, or fog and drizzle, at almost every station on the morning of the 3d.

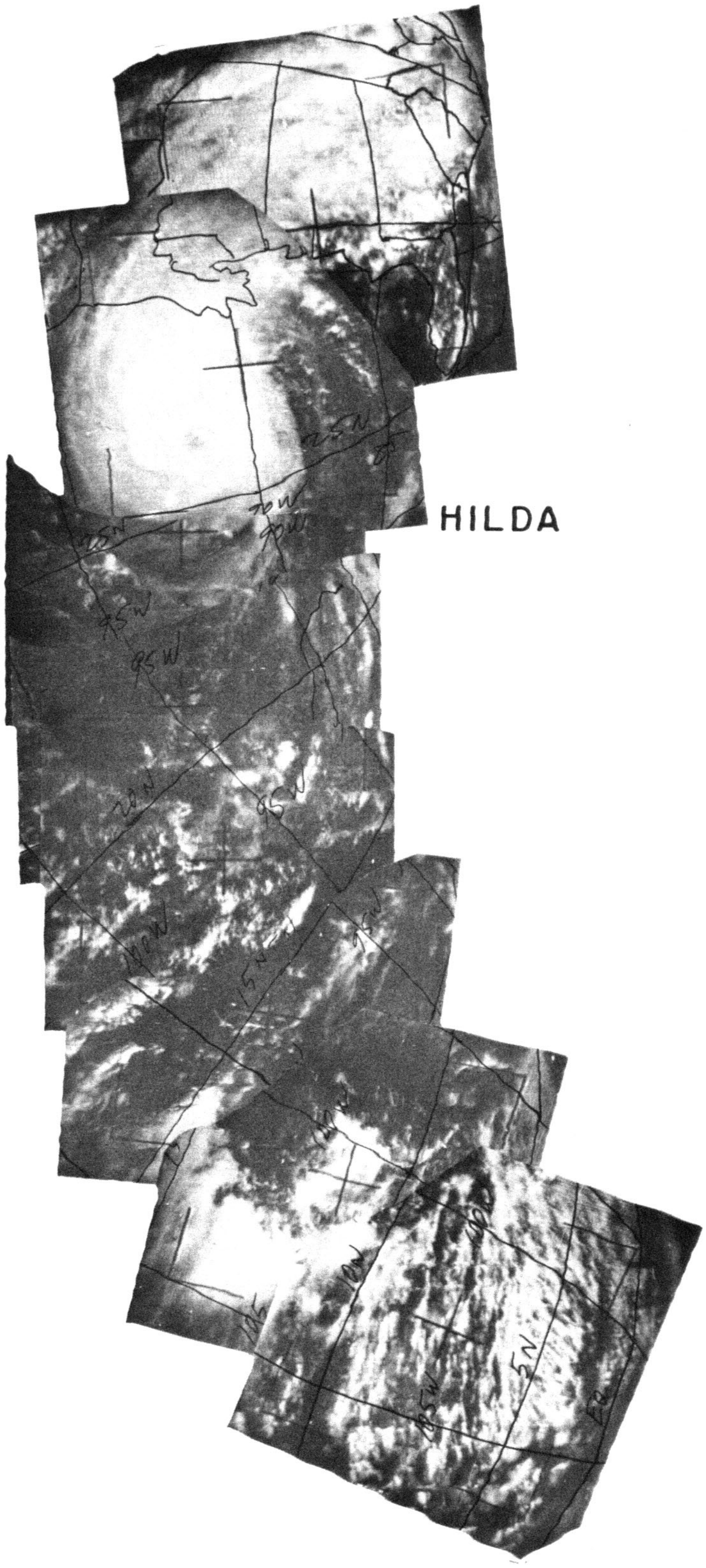

Figure 4.—TIROS VIII, Orbit 4152/51, view of hurricane Hilda at 1926 GMT on Oct. 2, 1964, showing the intermingling of the outflow cloudiness with frontal cloudiness over the southeastern States.

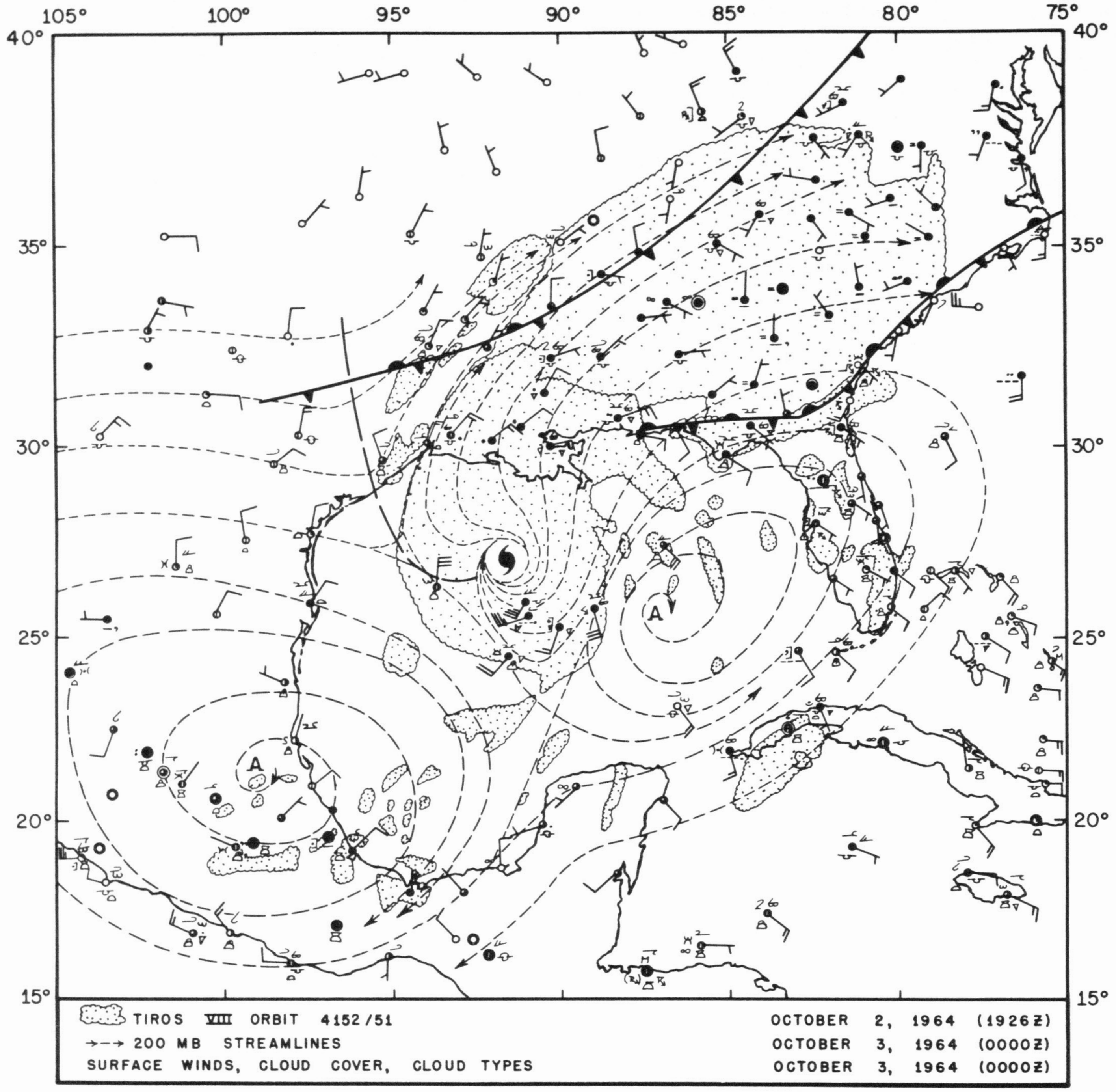

FIGURE 5.—Nephanalysis superimposed on 200-mb. streamlines and surface observations and fronts. The surface fronts substantiate the contention that the extensive cloud cover over the southeastern States is not caused solely by outflow from the hurricane.

The Valparaiso cross section (fig. 3) evidenced slightly lower temperatures on the soundings taken at 12 GMT of October 3 and 06 GMT of October 4. This minor cooling extended up through 500 mb. and occurred under intermittent shower conditions. At higher levels evidence of warmth in the outflow layer was readily apparent. At Lake Charles (fig. 1) temperature changes below 500 mb. were relatively minor through October 3. Aloft, however, the warm outflow layer appeared in increasing depth as time went on and the storm drew nearer. At the same time the reported tropopause height at Lake Charles rose from around 120 mb. to 105 mb. Such variations in tropopause height with the hurricane have been recently documented by Koteswaram [5] and generally support a higher (and colder) tropopause in the vicinity of the storm.

3. LANDFALL AND RECURVATURE

Hurricane Hilda made landfall during the evening of October 3. Franklin, La. (a coastal station), reported wind speeds of 120 m.p.h. and pressure of 962 mb. An oil rig in the Gulf some 100 mi. south of Morgan City, La., claimed that winds "pegged the anemometer" on its maximum reading of 120 m.p.h. but that substantially higher winds were experienced. Huge waves were estimated to be nearly 50 ft. high.

After more than half of the storm was over land it began to fill at the extremely rapid rate of some 2 to 4 mb./hr. This continued for some 10 to 12 hr., after which the filling decreased to about ⅛ of this amount. Such rapid filling over land was not unprecedented but it was extremely rapid—about twice the rate at which hurricane Donna filled when it went ashore over the Florida peninsula in 1960 (Miller [6]). This rapid rate may be attributed, in part at least, to the cold dry air that dominated the mainland. After the oceanic heat and moisture source were effectively removed, this sharply contrasting air entered the system at low levels. With but short overwater trajectories the air was not modified sufficiently to maintain Hilda in the 960- to 965-mb. range.

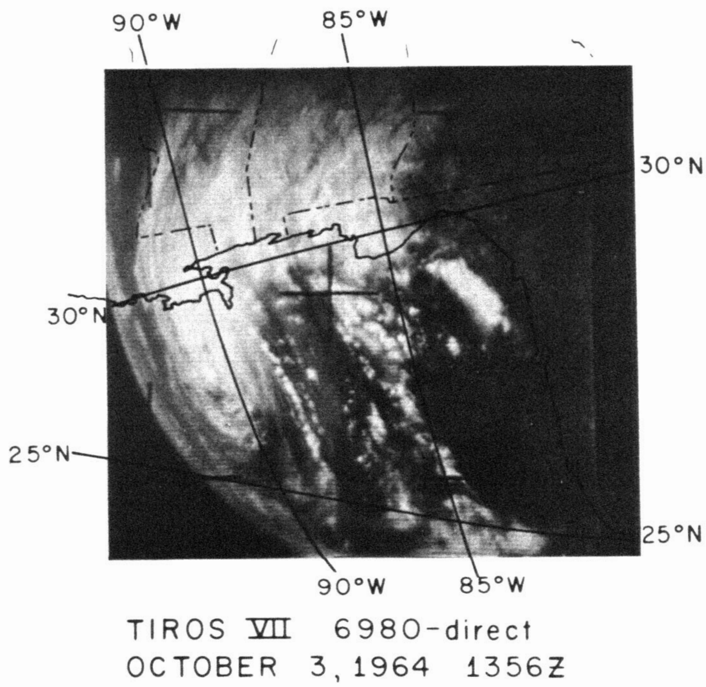

FIGURE 6.—An oblique view of hurricane Hilda from TIROS VII on October 3, the last day before landfall.

We have added to the time-space cross section for Lake Charles (fig. 1) the anomalies of temperature for hurricane Hilda (which were established on October 1) for radial distances of 75 and 50 n.mi. Although these anomalies characterized the storm at a deeper stage than the one prevailing shortly after 00 GMT on October 4, the two fields of anomalies blend together into a reasonable fit and give a fair idea of the general structure of the northwest side of the storm on something approaching a synoptic scale. In view of our lack of detailed knowledge of the central structure of the storm at this time, no compositing was attempted over the inner 50 mi. at 12 GMT on October 4.

Lake Charles lay about 140 n.mi. to the rear as the storm turned eastward. The warm outflow air aloft was very much in evidence. At low levels some cooler (but not cold) surface air was entering the system, and temperatures were below the tropical normal up to 700 mb. This low level cold air intrusion intensified markedly over the succeeding 12 hr. as the Low acquired extratropical characteristics and the fresh cold air was drawn into the system. During these 12 hr. (preceding 00 GMT of the 5th) the upper level outflow layer almost disappeared over Lake Charles. The satellite did not get a picture of the center of Hilda on October 4, but it did obtain a very interesting view of the outflow from the dying storm. Figure 8 presents a remarkable photograph, used by Johnson [4], who stated: "The sharp western edge of the cirrus formation, which is especially well developed in this case, is a condition that occurs commonly along the outer edge of anticyclonically curving major cirrus formations associated with well-developed upper tropospheric jet currents. . . ." He also concluded that the western edges of the cirrus outflow were at lower elevations (around 300 mb.) than the brighter cirrus farther to the east. On the basis of our 300-mb. streamline analysis for 12 GMT, October 4 (fig. 9), the nephanalysis was fitted to the winds on the assumption that the earlier gridding had inadvertently placed the cloud formation 5° too far west.

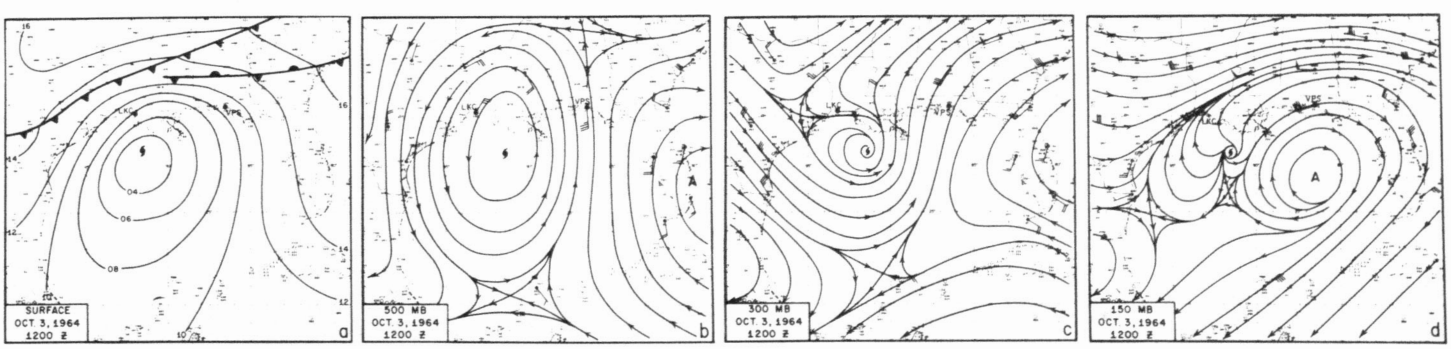

FIGURE 7.—Maps at 12 GMT, October 3: (a) surface isobars showing that Hilda had grown to a fairly large size before it went ashore on the Louisiana coast; (b) 500-mb. streamlines also showing expanded circulation of Hilda; (c) 300-mb. streamlines showing the vortex in a long wave trough; and (d) 150-mb. streamlines showing the upper level outflow.

Aside from the jet stream aspects, the confluence of air streams from different source regions with differing characteristics provides an excellent opportunity for the formation of a sharp-edged cirrus band. The properties of the jet stream may well tend to preserve this discontinuity in the confluencing air streams.

The sea level chart for 12 GMT, October 4 (fig. 9a), shows tropical storm Hilda centered over eastern Louisiana. A cold front newly arrived from the northwest was on the point of entering the storm which had been downgraded to tropical storm status during the night. At 500 mb. (fig. 9b), the size of the cyclonic vortex had diminished over the intervening 24 hr. The trough in which the vortex was embedded had acquired baroclinic characteristics, with the air to the rear significantly cooler than the air ahead. At 150 mb. (fig. 9d), all vestiges of a closed circulation had just disappeared. The last of the warm air associated with the hurricane (at 150 mb.) was being swept from the area. At 00 GMT on the 4th (charts not shown), both a closed cyclonic center directly over the storm and an anticyclonic center just south of Lake Charles still existed. Consequently, the configuration of figure 9d is a very recent simplification of the previous pattern. In support of this view the tropopause reached its highest level (100 mb.) at this observation and began lowering thereafter. Twelve hr. later it was down at 110 mb.

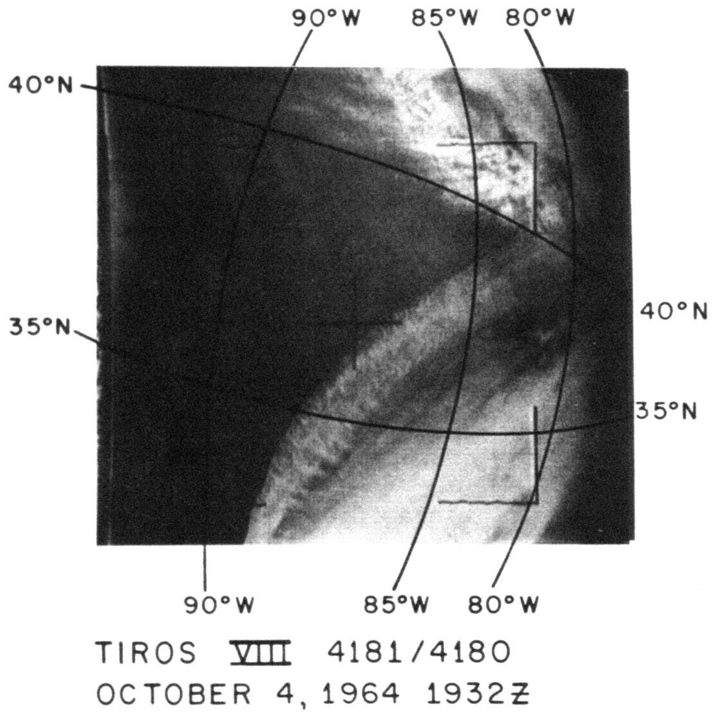

FIGURE 8.—Satellite view of the cirrus outflow from the rapidly disintegrating remnants of Hilda. The darker cirrus band on the left has been interpreted as somewhat lower (around 300 mb.) than the brighter area to the east (cf. fig. 9c).

As the Low moved eastward just about over the middle of the Florida panhandle, Valparaiso remained in the warm sector of the new extratropical wave until around 03 GMT on October 5. The time section at Valparaiso (fig. 3) suggests that the cold wedge was well entrenched by 06 GMT of the 5th and that little of the thermal structure of the hurricane remained over the station. By 12 GMT of the 5th, there was adequate evidence of a cold front between Valparaiso and Jacksonville, Fla. The cross section from San Antonio to Jacksonville (fig. 10) shows well-marked discontinuities in wind and temperature accompained the strong frontal push to the rear of the new extratropical wave. Because the reported tropopause heights at Valparaiso seemed to vary somewhat unreasonably, we did not try to incorporate them in this report but they have been entered on figure 3.

4. FLOODING POTENTIAL

The latter stages of hurricane Hilda posed a significant disaster potential. Since much of New Orleans lies below sea level, the city is susceptible to serious flooding. If Hilda had recurved just a little sooner and come north to the east of New Orleans, it would have forced large amounts of water into Lake Pontchartrain. If it had also maintained its hurricane intensity, much of this water would have been spilled by northwesterly winds from the

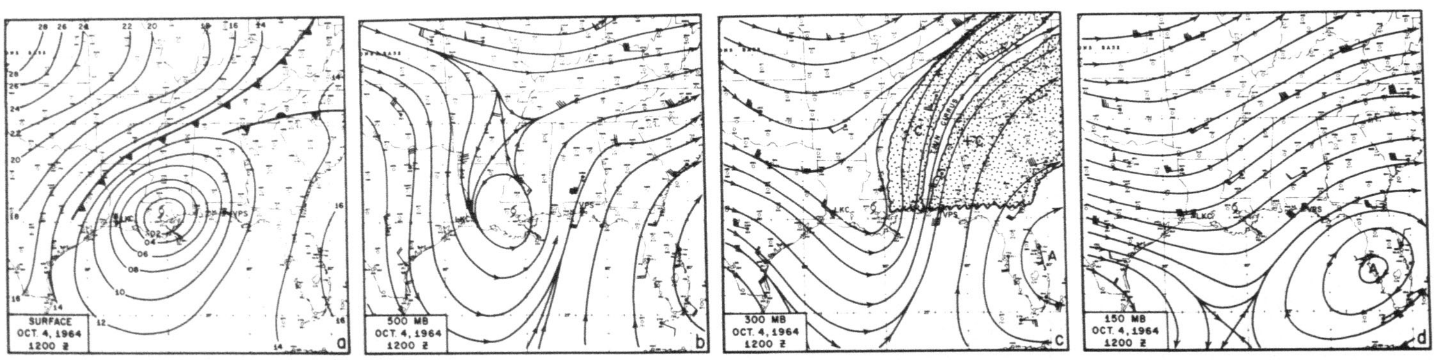

FIGURE 9.—Maps at 12 GMT, October 4: (a) surface isobars and fronts, which are about to enter tropical storm Hilda; (b) 500-mb. streamlines showing the opening of the old vortex into a westerly trough; (c) 300-mb. streamlines showing their orientation relative to the western edge of the cirrus shield, which was estimated to be at 300 mb.; (d) 150-mb. streamlines. Complete absence of any closed circulation at 150-mb. and probable absence at 300 mb. are indicative of the rapid modification in the structure of Hilda.

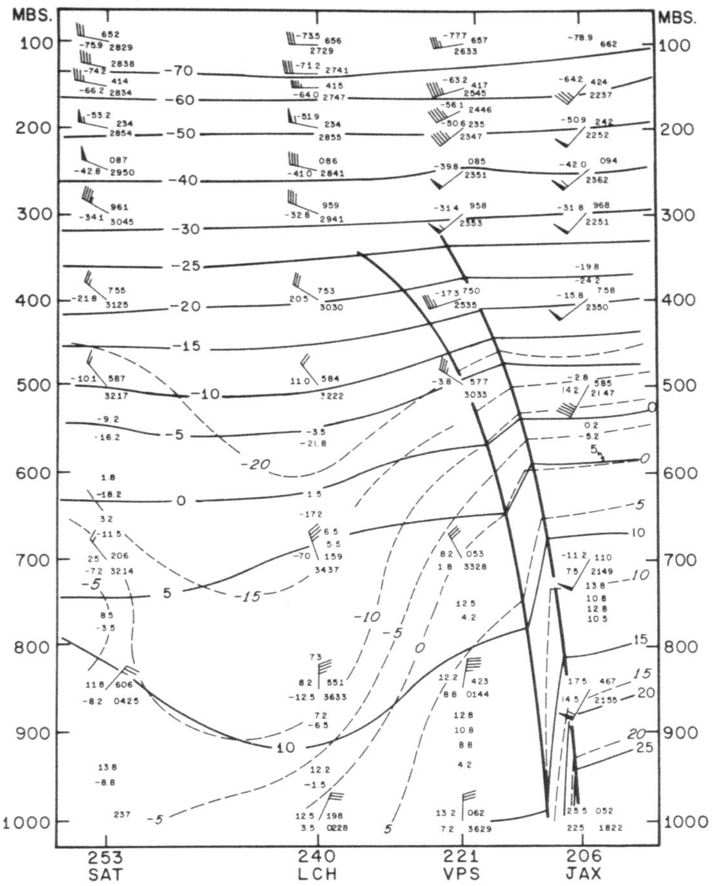

FIGURE 10.—Cross section from San Antonio, Tex., to Jacksonville, Fla., for 12 GMT Oct. 5, 1964. A vigorous cold front is shown approaching Jacksonville as the extratropical wave resulting from hurricane Hilda passes off the coast. Heavy black lines show approximate limits of the layer of discontinuity. Solid lines are isotherms and dashed lines connect locations at equal dewpoints; both are labelled in °C.

Lake into the low-lying city, affecting some half million people (Dunn and Staff [1]). In this instance the forecasts were admirably phrased and correctly gaged the track of the storm.

5. SUMMARY

Hurricane Hilda approached the Gulf Coast as a 960- to 965-mb. storm with winds of at least 125 m.p.h. The continent was overlaid with cool polar air which was reinforced by a new burst just as Hilda arrived. Evidence of the outflow from the hurricane could be found in the 150- to 300-mb. layer and in the satellite photographs. Nevertheless, temperatures in the outflow were not exceedingly high when compared with temperatures found in the core of the hurricane, a fact attributable to mixing and to radiational cooling.

After the landfall, Hilda filled at an exceptionally rapid rate possibly because of the cool, dry environment. The closed circulations at 150, 200, and probably 300 mb. had disintegrated before the storm had been ashore 12 hr. Baroclinic structure then became evident and the remnants of Hilda moved eastward as an extratropical depression.

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